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Description of a new *Follicucullus* species from Southwest Japan

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One of an important index for the late Middle to early Late Permian, species of *Follicucullus* Ormiston and Babcock is reexamined in view point of stratigraphic occurrence, biogeographic distribution and morphology. Japanese *Follicucullus* which has been regarded to be *F. ventricosus* Ormiston and Babcock or treated as *Follicucullus scholasticus* Ormiston and Babcock morphotype II of Ishiga is described as a new species of *Follicucullus*. Evolutional trend of *Follicucullus* is discussed and a new lineage zone of *Follicucullus* is proposed.

Introduction

Follicucullus Ormiston and Babcock is an important key of the late Middle to early Late Permian time for their unique forms characteristic of Late Paleozoic Albaillellaria, and rather short range of occurrence. Among several species of this genus, *F. scholasticus* and *F. ventricosus* were first described from the Lamar Limestone of the Delaware Basin of Texas (Ormiston and Babcock, 1979), and subsequently some species have described from Japan and Circum Pacific regions. The latter forms of *Follicucullus* show different forms than that of the original description of *Follicucullus ventricosus*. Paleontologic assessment of *Follicucullus* together with these points of view endorses the significance of radiolarian study of the Late Paleozoic geography.

Morphology of *Follicucullus*

Follicucullus is characterized by conical shell consisting of apical cone, pseudothorax and pseudoabdomen and this terminology is applied from that of *Pseudoalbaillella*. Species of *Follicucullus* are described by feature of the shell construction as follows:

1 possession of wing at apical cone=*F. monacanthus*
2 inflation of pseudothorax
  a bigger ventral flap=*F. ventricosus*
  b bigger dorsal flap=*F. charveti*
3 elongated conical shell
  a conical shell without inflation of pseudothorax=*F. scholasticus* m. I
  b undulated shell and inflation of pseudothorax=*F. scholasticus* m. II

c curved apical cone=*F. bibartitus*

Among the species listed above, a determination of *F. scholasticus* morphotype I and *F. scholasticus* m. II is sometimes very hard but proportion of shell represented by the ratio W/L (where W is the width of pseudothorax and L is the length of shell, see Ishiga, 1984, 1986) is useful attempt of the identification of two forms. However, as indicated hitherto the literature of *Follicucullus*, *F. scholasticus* m. II was regarded to be *F. ventricosus*, because of the variety of *F. scholasticus* m. II and lacking of other characteristic feature of this form. Moreover, *F. scholasticus* m. II differs geologic and geographic distribution from other *Follicucullus* eventhough compared to that of *F. scholasticus* m. I. Thus the *Follicucullus scholasticus* morphotype II should be described as an independent species in order to avoid confusion of the determination of *Follicucullus*. Description of this new species is given in the next chapter.

Systematic Paleontology

Subclass Radiolaria Müller, 1858
Superorder Polycystina Ehrenberg, 1838, emend. Riedel, 1967
Suborder Albaillellaria Deflandre, 1953, emend. Holdsworth, 1969
Family Follicucullidae Ormiston and Babcock, 1979, emend. Kozur, 1981

Genus *Follicucullus* Ormiston and Babcock, 1979

Type species. *Follicucullus ventricosus* Ormiston and Babcock, 1979, p. 331, pl. 1, figs. 6–14.

Follicucullus japonicus Ishiga n. sp.

Pl. 1, Figs. 1–22; Pl. 2, Fig. 1

1980 *Follicucullus scholasticus* Ormiston and Babcock, Ishiga and Imoto, pl. 4, figs. 5–7.
1982a *Follicucullus scholasticus* Ormiston and Babcock, Ishiga et al., pl. 3, fig. 9.
1982b *Follicucullus scholasticus* Ormiston and Babcock, Ishiga et al., pl. 2, figs. 8–10.
1982 *Follicucullus scholasticus* Ormiston and Babcock, Kojima, pl. 3, fig. 4.
1982 *Follicucullus scholasticus* Ormiston and Babcock, Sato et al., pl. 1, fig. 5.
1982c *Follicucullus scholasticus* Ormiston and Babcock, Ishiga et al., pl. 4, figs. 13, 14.
1982 *Follicucullus scholasticus* Ormiston and Babcock, Nishizono et al., pl. 2, fig. 3.
1983 *Follicucullus scholasticus* Ormiston and Babcock, Wakita, pl. 5, fig. 8.
1983 *Follicucullus scholasticus* Ormiston and Babcock, Suyari et al., pl. 3, figs. 1–9.
1985 *Follicucullus scholasticus* Ormiston and Babcock, Sashida and Tonishi, pl. 7, figs. 1, 3, 7, 17.
1989 *Follicucullus scholasticus* Ormiston and Babcock, Nishimura et al., pl. 1, figs. 1, 2.

1990 *Follicucullus scholasticus* Ormiston and Babcock, Kurimoto, pl. 1, fig. 20.
1990 *Follicucullus scholasticus* Ormiston and Babcock, Okada, pl. 1, figs. 6, 8, 9.
1988 *Follicucullus scholasticus* Ormiston and Babcock morphotype I, De Wever et al., fig. A.
1984 *Follicucullus scholasticus* Ormiston and Babcock morphotype II, Ishiga, pl. 1, figs. 1–8.
1985 *Follicucullus scholasticus* Ormiston and Babcock morphotype II, Ishiga, pl. 1, figs. 22–28.
1986 *Follicucullus scholasticus* Ormiston and Babcock morphotype II, Miyamoto and Tanimoto, pl. 1, figs. 9, 10.
1986 *Follicucullus scholasticus* Ormiston and Babcock morphotype II, Ishiga and Miyamoto, pl. 64, figs. 9–11.
1987 *Follicucullus scholasticus* Ormiston and Babcock morphotype II, Nishimura and Ishiga, pl. 1, figs. 4–6.
1987 *Follicucullus scholasticus* Ormiston and Babcock morphotype II, Pillai and Ishiga, pl. 1, figs. 9, 10.
1988 *Follicucullus scholasticus* Ormiston and Babcock morphotype II, Ishiga, p. 50, pl., figs. 3, 4.
1989 *Follicucullus scholasticus* Ormiston and Babcock morphotype II, Kurimoto, pl. 2, figs. 5, 6.

1983 *Follicucullus* sp. aff. *F. scholasticus* Ormiston and Babcock, Wakita, pl. 5, fig. 9.

1982 *Follicucullus ventricosus* Ormiston and Babcock, Kojima, pl. 3, figs. 2, 3.
1982 *Follicucullus ventricosus* Ormiston and Babcock, Sato et al., pl. 1, figs. 6–8.
1983 *Follicucullus ventricosus* Ormiston and Babcock, Suyari et al., pl. 4, figs. 6, 7, 10.
1986 *Follicucullus ventricosus* Ormiston and Babcock, Kojima, figs. 3, 5.
1982 *Follicucullus ventricosus* Ormiston and Babcock, Wu and Li, pl. I, fig. 16.

1983 *Follicucullus* sp. cfr. *F. ventricosus* Ormiston and Babcock, Wakita, pl. 5, fig. 7.
1986 *Follicucullus* sp., Kojima, figs. 3, 4.

cfr. 1989 *Follicucullus* sp. cfr. *F. scholasticus* Ormiston and Babcock, Cheng, pl. 2, fig. 7.

non 1981 *Follicucullus scholasticus* Ormiston and Babcock, Takemura and Nakaseko, pl. 34, fig. 6.
non 1979 *Follicucullus scholasticus* Ormiston and Babcock, p. 331, figs. 1–5.
non 1980 *Follicucullus scholasticus* Ormiston and Babcock, Ishiga and Imoto, pl. 4, figs. 8–10.
non 1983 *Follicucullus scholasticus* Ormiston and Babcock, Wakita, pl. 5, fig. 8.

Materials. *Follicucullus japonicus* n. sp. occurring in the *Neoalbaillella optima* zone is best reserved in detailed feature of shell surface. The types are selected from the materials from the bedded cherts of the Nabejiri-yama area reported by Ishiga et al. (1982a). Holotype KUE PR 54–33 (Pl. 1, Fig. 5), paratype KUE PR 46–51 (Pl. 1, Fig. 1), KUE PR 54–38 (Pl. 1, Fig. 2), KUE PR 46–49 (Pl. 1, Fig. 3), KUE PR 54–21 (Pl. 1, Fig. 4), KUE PR 46–56 (Pl. 1, Fig. 6), KUE PR 46–55 (Pl. 1, Fig. 7), KUE PR 46–57 (Pl. 1, Fig. 8), which are deposited in the Department of Geosciences, Kyoto University of Education.

Measurements. Morphological difference of *F. scholasticus* m. I. and *F. scholasticus* m. II. (*F. japonicus* n. sp.) was discussed in Ishiga (1984, 1986) and, measurements of *Follicucullus japonicus* n. sp. is given in Fig. 1, which is cited from fig. 3 on p. 4 of Ishiga (1986). The diagram shows clear distinction of *F. japonicus* n. sp. from *F. scholasticus* (s.s.) (previous *F. scholasticus* m. I). In this diagram, measurements of *F. ventricosus* from Texas are also given for comparison of morphology of these *Follicucullus*.

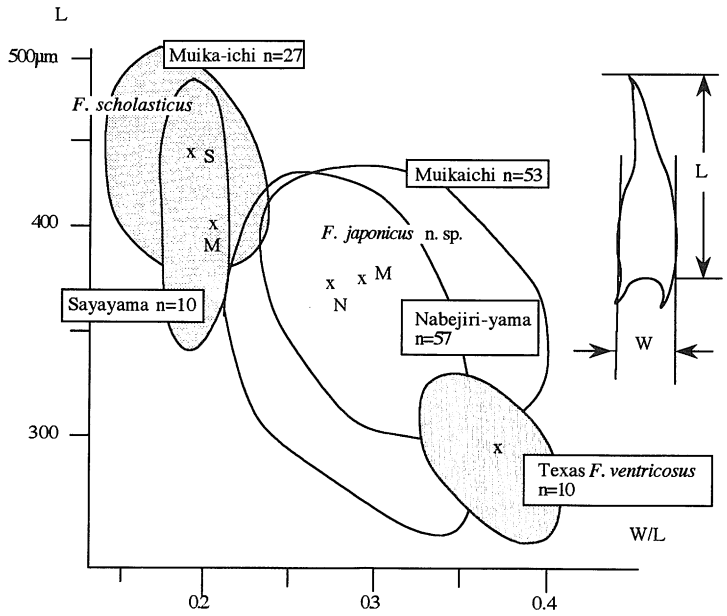

Fig. 1. Measurements of *Follicucullus scholasticus* Ormiston and Babcock and *F. japonicus* n. sp. after Ishiga (1986). ×; showing average of the measurements. S; Sasayama specimens. M; Muika-ichi specimens. N; Nabejiri-yamama specimens.

Specific diagnosis. A species of *Follicucullus* characterized by conical shell weakly differentiated by inflation of pseudothorax, into apical cone, pseudothorax without wing, and pseudoabdomen with small flaps.

Remarks. Since Ishiga and Imoto (1980) showed two types of *Follicucullus scholasticus*, identification of both *F. scholasticus* and *F. ventricosus* has been different among the literatures. This is due to the lacking of an examination of the topotype specimen of *Follicucullus* from Texas and probable misunderstanding of the word "sinus". The sinus of original meaning indicates the groove running along the dorsal side of shell which is characteristic and diagnostic feature of *F. ventricosus*.

Variation. Two variation (var. A and var. B) of *F. japonicus* n. sp. are discriminated. Var. A (Pl. 1, Figs. 16–18) is characterized by inflated pseudothorax (middle portion of shell), and is a supposed ancester of *F. charveti*, while var. B (Pl. 1, Figs. 19–21) has a slender shell closely related W/L ratio to that of *F. scholasticus*. However this form is characterized by clear undulation of shell surface, which discriminates this species from *F. scholasticus*.

Comparison. *Follicucullus japonicus* n. sp. differs from *F. ventricosus* in which the latter species shows larger ratio W/L, strongly inflated pseudothorax giving a distinction of apical cone, pseudothorax and pseudoabdomen, and groove (originally described as the "sinus" by Ormiston and Babcock, 1979).

Occurrence. *Follicucullus japonicus* n. sp. occurs from the late Middle to early Late Permian bedded chert clasts of the Jurassic melange of the B terrane-group, and clastic rocks of the A terrane-group (cfr. occurrence of *F. scholasticus* morphotype II in Ishiga, 1990).

Evolutional trend of *Follicucullus*

The first appearance of *Follicucullus* is the base of *F. monacanthus* zone described from the siliceous rocks of the Tamba Terrane, Southwest Japan (Ishiga et al., 1982b), of which species is characterized by dorsal wing. The possession of the wing even-though it is asymmetric one, suggests connection of *Pseudoalbaillella* and *Follicucullus*. Probable ancestor of *F. monacanthus* is *Pseudoalbaillella* sp. cfr. *P. fusiformis* (Nishimura and Ishiga, 1987). *F. monacanthus* produced *Follicucullus scholasticus* morphotype II group (Ishiga, 1984)[1], which is hitherto described as *F. ventricosus*, *F. scholasticus* and/or *Follicucullus scholasticus* m. II.

Follicucullus scholasticus m. II evolved in two different ways, which is regarded to be caused by paleobiogeographic distribution of the *Follicucullus* stock. *F. bipartitus-F. charveti* stock (assemblage) was produced in characteristic regime such as the Ultra-Tamba Terrane and Kurosegawa Terrane of the A terrane-group, while *F. scholasticus* m. II stock appeared in pelagic sediments of Jurassic accreted rocks of the B terrane-

[1] The group is tentatively used for the morphological variety of the species.

group (Ishiga, 1990). Noteworthy is the limited occurrence of *F. bipartitus-F. charveti* assemblage in clastic formation, but recently *F. charveti* has reported from bedded chert of the B terrane-group rocks. *Follicucullus scholasticus* m. I occurs exceptionally in bedded chert of the Tamba Terrane (Ishiga and Imoto, 1980), however its occurrence is restricted in clastic rocks of the A terrane-group (Ishiga, 1986).

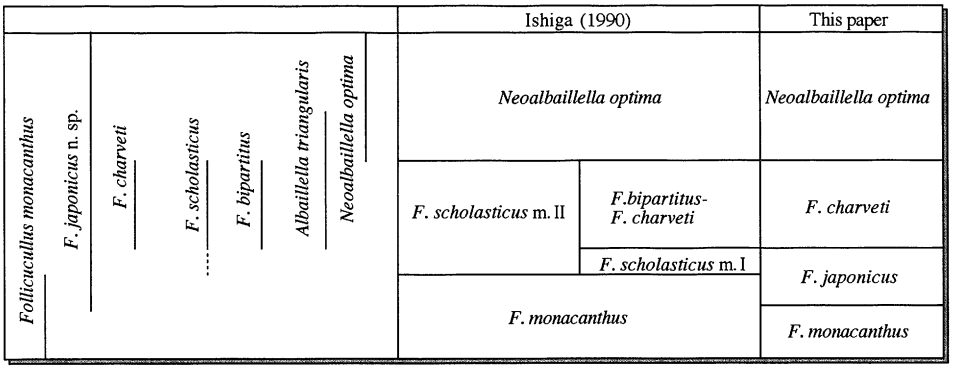

Fig. 2. Radiolarian zones of late Middle to early Late Permian of Southwest Japan. Redefined from Ishiga (1986, 1990).

Zones of *Follicucullus*

Follicucullus monacanthus zone is covered by zones of species of *Follicucullus*, which represents two lineages of *Follicucullus* stock. One is composed of the *F. scholasticus* m. I Zone below and the *F. bipartitus-F. charveti* Assemblage-zone upper and which together with covers the *Follicucullus scholasticus* m. II Zone (Ishiga, 1990).

Follicucullus bipartitus and *F. charveti* occur in bedded cherts of the upper part of the *F. scholasticus* m. II Zone (judging from Cheng, 1989).

Late Middle to early Late Permian radiolarian zonation is settled by species of *Follicucullus* and two suites of assemblages appeared in mutually different geographic domains (Ishiga, 1986a, b, 1990). One is *F. monacanthus* Zone, *F. scholasticus* m. I Zone and *F. bipartitus-F. charveti* Assemblage-zone, and the other is the *F. scholasticus* m. II Zone which includes latter two zones (Ishiga, 1990). The first appearance of *F. japonicus* is approximately middle part of the *F. monacanthus* Zone and this zone was range-zone (Ishiga, 1986a). If the *Follicucullus* is redefined by taking into consideration of the lineage of species of *Follicucullus*, proposed zones are settled as follows in ascending order.

Follicucullus monacanthus, Follicucullus japonicus and *Follicucullus charveti* zones which are defined below.

Follicucullus monacanthus zone

The *Follicucullus monacanthus* Range-zone was originally defined by the range of

occurrence of this species, but this occurs from the *Neoalbaillella* cherts of the Mino-Tamba Terrane. Thus the reassessment of the whole range of this species is required for certification of *Follicucullus* zones. As mentionaed above, subdivision of upper Middle to lower Upper Permian by the lineage of *Follicucullus monacanthus-F. japonicus-* and *F. charveti* is preferable than that of previous zonation.

Distribution: The zone of *Follicucullus monacanthus* is distributed in bedded chert sequence in the Mino-Tamba Terrane of the B terrane-group and also is recognized in the black mudstones and acidic tuffs of the Maizuru and Akiyoshi Terranes of the A terrane-group (see Ishiga, 1986).

Definition: The base of the zone is defined by the first occurrence of *F. monacanthus* and the top is marked by the first occurrence of *F. japonicus*.

Remarks: The zone corresponds to the lower part of the *F. monacanthus* Range-zone of Ishiga (1986).

Age: *F. monacanthus* occurs from the siliceous rocks intercalating *Lepidolina multiseptata* bearing limestone conglomerates in the Atetsu area of Southwest Japan (Yamashita and Ishiga, 1990). According to three folds of subdivision of the Permian by fusulinids zonation (Ishii, 1990), the boundary between Upper and Middle Permian is defined by that of *Yabeina globosa*/*Lepidolina multiseptata shiraiwansis* zone and the *Lepidolina kumaensis* and/or *Nanlingella simplex*-(*Colaniella minima*) (*Codonofusiella-Reichelina*) zone. If this zonation is applied to correlate to radiolarian zonation, the *F. monacanthus* zone corresponds to some part of the *L. m. shiraiwensis* zone of Ishii (1990).

Follicucullus japonicus zone

Distribution: The zone of *Follicucullus japonicus* is distributed in bedded chert sequences in the Mino-Tamba Terrane of the B terrane-group and also is recognized in the black mudstones and acidic tuffs of the Maizuru and Akiyoshi Terranes of the A terrane-group (see Ishiga, 1986).

Definition: The base of the zone is defined by the first occurrence of *F. japonicus* and the top is marked by the first occurrence of *F. charveti.*

Remarks: The zone includes upper part of the *F. monacanthus* Range-zone of Ishiga (1986) and lower part of the *F. scholasticus* Assemblage-zone of Ishiga (1986). The zone also includes the *F. scholasticus* morphotype I zone of Ishiga (1990).

Age: This zone covers the *Follicucullus monacanthus* zone described above, and is covered by the *Follicucullus charveti* zone which is supposed to be early Late Permian mentioned below.

Follicucullus charveti zone

Between the *F. japonicus* and the *Neoalbaillella optima* zones occurrence of characteristic fauna composed of *F. bipartitus, F. charveti* and *Albaillella triangularis* is known. And an interesting situation is of limited occurrence of the *Follicucullus*

bipartitus-F. charveti Assemblage among the late Permian rocks of the Ultra-Tamba Terrane and the Kurosegawa Terrane (cfr. Ishiga 1986, 1990). This is a supposed same paleobiogeographic situation to that of the *Lepidolina kumaensis* fauna (Ishii, 1986). *F. charveti* is a dominant species of this assemblage and occurs from the bedded cherts of the B terrane-group. Thus *F. charveti* is preferable to represent the "*F. bipartitus-F. charveti* Assemblage" and the *F. charveti* zone is defined herein.

Definition: The base of the zone is defined by the first occurrence of *F. charveti* and the top is marked by the first occurrence of *Neoalbaillella optima* Ishiga, Kito and Imoto. The base is also corresponds to the first occurrence of *Albaillella triangularis* Ishiga, Kito and Imoto.

Comparison: The *F. charveti* zone corresponds to the *F. bipartitus-F. charveti* Assemblage-zone of Ishiga (1990).

Age: The *F. bipartitus-F. charveti* Assembnlage-zone corresponds to the horizon of the *Lepidolina kumaensis* bearing limestone conglomerates of the Kuma Formation, Kyushu Japan (Ishiga and Miyamoto, 1986). Thus the base of the *Follicucullus charveti* zone corresponds to the boundary of Upper/Middle Permian of Japan, on the basis of Ishii's fusulinids zonation.

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Imoto, N. of Kyoto University of Education provided samples bearing topotypes of *Follicucullus ventricosus* from Texas.

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(J) in Japanese. (J, E) in Japanese with English abstract. (C, E) in Chinese with English abstract.

Explanation of Plates

Plate 1

Figs. 1–15. *Follicucullus japonicus* n. sp. Ishiga.

Fig. 1, KUE PR (registered number of Kyoto University of Education) 46–51. 2, 54–38. 3, 46–49. 4, 54–12. 5, 54–33. 6, 46–56. 7, 46–55. 8, 46–57. 9, 54–17. 10, 54–18. 11, 54–51. 12, 54–29. 13, 54–24. 14, 54–37. 15, 54–63.

Figs. 16–18. *Follicuculus japonicus* n. sp. var. A.

Fig. 16, KUE PR 54–22. 17, 54–3. 18, 54–4.

Figs. 19–21. *Follicucullus japonicus* n. sp. var. B.

Fig. 19, KUE PR 56–53. 20, 56–54. 21, 46–48.

Fig. 22. *Follicucullus scholasticus* Ormiston and Babcock.

Fig. 22, KUE PR 46–52.

Specimens illustrated in this plate are from sample 23 of Nabejiri-yama area of Ishiga et al. (1982a). Scale bars (for all figures): 100 μm.

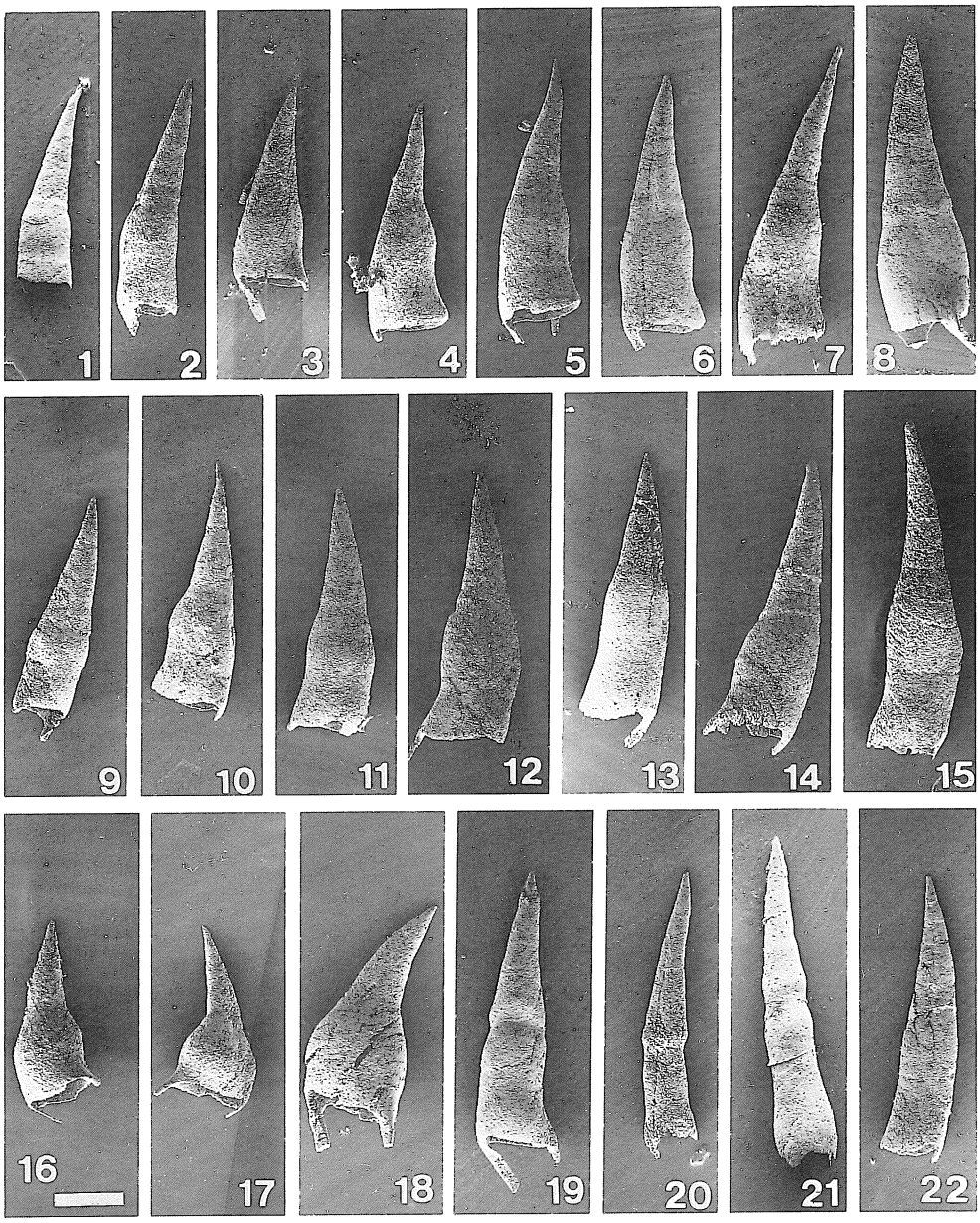
Plate 2

Figs. 1–4. are stereoscopic pairs.

Fig. 1. *Follicuculls japonicus* n. sp. from sample 23 of Nabejiri-yama area of Ishiga et al., (1982a). SU PR 1021 (Registered number of the Shimane University). Note the lamellar of the shell surface (cuticle like structure), developed from apical portion to the aperture. The edge of the lamellar covers the lower ones, and along this margin small pores are arranged in a row.

Fig. 2. *Follicucullus scholasticus* Ormiston and Babcock from sample 23 of Nabejiri-yama area of Ishiga et al. (1982a). SU PR 1022. Ventral side of the shell.

Figs. 3, 4. *Follicucullus ventricosus* Ormiston and Babcock topotype specimens. Scale bars 100 μm. SU PR 1023 (Fig. 3), SU PR 1024 (Fig. 4).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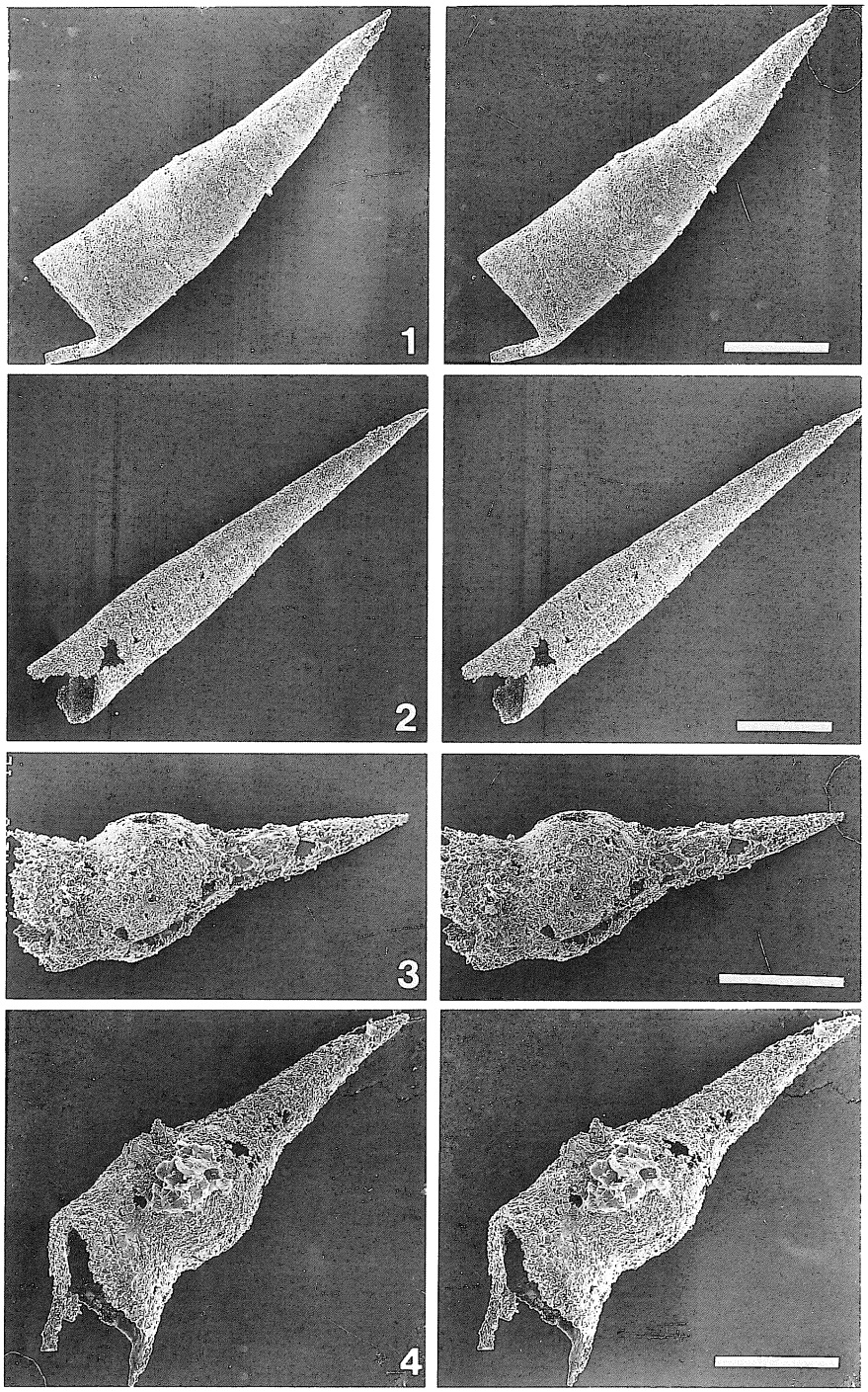
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